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ORCHARD STUDIES—XV. The Bitter Rot of Apples.

Wm. B. Alwood.

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THE BITTER ROT OF APPLES.

Glomorella rufomaculans (Berk)

(Spaulding and Von Schrenk.)

In Bulletin No. 40, of this station, dated October, 1894, we published some studies on the ripe rot or bitter rot of apples. That Bulletin has, however, been out of print for several years, and as this trouble of the apple orchards is causing very considerable losses to the fruit growers of the State, the present appears to be an opportune moment for reprinting in part this former Bulletin, and adding some more recent data to the matter therein contained.

HOST PLANTS OF THE BITTER ROT FUNGUS.

It is well known to specialists that the fungus plant which causes the disease of the apple fruit known as bitter rot occurs naturally upon several other pomaceous fruits; on a number of the stone fruits, as nectarines and peaches; on ripe grapes; and it has been successfully cultivated on the fruits of tomato, eggplant, pepper, squash, banana, and others. While it thus appears to be possible for this fungus to adapt itself to a great variety of hosts, yet from our observation in this State, it would seem that, aside from the occurrence on apple and pear, these others are incidental hosts, hence have little concern for the practical orchardist. This parasitic fungus is very persistent in its attack upon apples especially, and to a lesser extent upon pears, and propagates itself with great rapidity when weather conditions are favorable, consequently it has now come to be the all-important disease of the maturing fruit in the apple orchards.

HISTORICAL NOTE AND NOMENCLATURE.

There is now quite universal agreement that the fungus discovered by the Rev. M. J. Berkeley in 1854, causing a ripe rot of grape, and named by him *Septoria rufo-maculans*, is none other than the

fungus now so generally recognized as the cause of the trouble under discussion in this article. Two years later, in 1856, Berkeley described a fungus causing a rot of apples, and named it *Gloeosporium fructigenum*, which name, with slight temporary changes, has stood down to within the last two years as the scientific name of the parasitic fungus which causes this most widespread disease of apples. This account of Berkeley's, dated 1856, is the first notice of the bitter rot of apples thus far discovered in the literature of plant diseases.

In 1859 Berkeley again described a fungus causing a fruit rot—this time on peaches and nectarines—and named it *Gloeosporium laeticolor*; then again in 1874 Berkeley and Curtiss (M. A.) described a fungus causing rot on apples, received from South Carolina, as *Gloeosporium versicolor*, thus making four supposedly original descriptions of fungi causing fruit rots, which it now appears are caused by one and the same fungus. While this has not been absolutely proven, cultures of these rots on various fruits and a better knowledge of the variability of this fungus warrant this conclusion.

The form genus *Gloeosporium* contains many species of fungi of widely varying habit, but which for lack of more definite knowledge of their life histories are lumped together in this so-called genus. During the nearly fifty years that the bitter rot fungus has been known, no worker in mycology gave to it sufficient study to discover the final stages of its life cycle until within the past two years. In 1902 Mr. G. P. Clinton published in Bulletin 69, Illinois Agricultural Experiment Station, investigations carried on the previous year, which detailed the discovery of the asci bearing perithecia of this fungus in the decayed fruit, and in cultures made in the laboratory at the Illinois Agricultural Experiment Station. Accordingly he removed it from the form genus under which it had been so long known, and placed it under the genus *Gnomoniopsis* erected by Miss Bertha Stoneman in 1898 to receive several *Gloeosporium* species of which she had discovered the ascigerous fruit. During the same year, 1902, Messrs. Von Schrenk and Spaulding, in their investigations of this disease at the Mississippi Valley Laboratory of the Bureau of Plant Industry, United States Department of Agriculture, verified the discovery of Clinton, and also added the observation that the

ascigerous stage is found in cankers upon the limbs of apple trees. As the generic name *Gnomoniopsis*, used by Miss Stoneman, and later by Clinton, for the ascigerous stage of *Gloeosporium* forms was preoccupied by reason of its use by Berlese in 1892, for generic designation of a different group of fungi, Spaulding and Von Schrenk erected the genus *Glomorella* to receive these species now removed from *Gloeosporium*, and in accordance with the rules of priority, the specific name first used by Berkeley for the rot on grapes now becomes the correct name for this species. Therefore, out of a plentitude of names, the bitter rot fungus has, we will hope, reached a stable designation—viz., *Glomorella rufo-maculans*, as given by Spaulding and Von Schrenk in Bulletin 44, Bureau of Plant Industry, United States Department of Agriculture.

THE COMMON NAME.

It is not possible to state when or where the common name, "Bitter Rot," was first given to the decay of the apple fruit produced by this fungus. Apparently it has been in use for years, and botanists adopted it because of its being the common name by which growers designated this disease. It is quite universally true that when the fruit decays upon the trees from this disease, the affected portion becomes bitter, varying much in degree; but it is also true that under some circumstances the decayed tissue does not become bitter, and especially is this true in laboratory cultures. I have tasted the decayed fruit in laboratory cultures when no trace of bitterness could be detected. This common name is, on the whole, a suitable one for the disease as it occurs on apple, but now that it is established that this species occurs upon grape in some sections, and does not cause a bitter taste of the fruit, some writers on the subject have been led to propose another common name. Dr. Galloway and Miss Southworth have proposed the name "Ripe Rot of Grape and Apple," from the fact that this species attacks the apple when approaching maturity, and only occurs upon grapes at time of ripening. In my observations, I have found this fungus to occur upon apple when but half grown or earlier, but its attack constantly increases in severity, and is much more noticeable just previous to maturity. For some reasons it might seem that "Ripe Rot" would be the better common

name, but the name "Bitter Rot" is now so firmly placed in the literature that it will doubtless stand.

SEASON OF OCCURRENCE.

The period of attack begins in many instances when the fruit is not half grown, but its greatest severity is just prior to maturity of the fruit. It increases in severity rapidly during the latter part of the season, continuing even in the picked fruit if the temperature and other conditions are favorable.

"An instance of early occurrence has been under observation here for several years. The tree is doubtless a seedling—at least it is not a variety at present cultivated—but it is very vigorous and apparently healthy, and bears an abundant crop of medium sized apples of indifferent quality. Every year this tree is the hot-bed from which bitter rot starts over the orchard. The first occurrence on it is usually noted about the 20th of July, and the fruit is not ripe until the first of September; but if at maturity the sound fruits are selected, cleansed and isolated in sterilized dishes, more than one-half of them will subsequently develop bitter rot without further infection than has already occurred on the tree." This note was written in 1894, and though the tree mentioned was destroyed some years since, we have, however, had abundant opportunity to observe in the young orchard of the Experiment Station the same facts above stated. The variety orchard has been fruiting with some regularity for several years, and certain varieties have for several years rotted with great certainty, regardless of treatment. The more noted varieties which are so severely attacked in the early season are Bentley, Missouri Pippin, Ortley, Peach Pond, Pecks Pleasant, and some others. Chennango Strawberry is usually one of the very first to show the disease, but it never shows anything like such serious injury of the fruit as the others mentioned. Early Ripe is occasionally attacked, though it is very unusual for the early varieties to suffer from this trouble.

The past season (1903) the first outbreak of the disease was noted on Missouri Pippin, July 9th. At that date only one fruit was found attacked, but the fungus had already reached the stage of spore production. The young fruit was about one inch in diameter, hence not half grown. From this date constant examinations showed from day

to day the development of the disease on Bentley and Peach Pond, first a few isolated fruits here and there, until by July 21st the disease was in full progress on the varieties mentioned above as especially susceptible. No occurrence was recorded up to this date on other varieties.

In epitome this has been the history of this trouble for several years in the station orchards. After July 20th the disease spreads with great rapidity over the trees first attacked, and with considerable severity onto the fruits of other susceptible varieties. We have fully come to believe that treatment cannot be made effective on any sort of practicable basis on these varieties which are so extremely susceptible. By July 27th the trouble showed very markedly on a few varieties, but not until after the middle of September was any rot to speak of observed on the great majority of those varieties which were finally affected in the station orchards.

On July 14, 1903, I received specimens of Albemarle Pippin from Piedmont Virginia, showing very well developed cases of bitter rot, and from that on throughout the season it was reported from numerous points, both in the Piedmont and the Valley districts of the State. The first specimens of fruit received were about one and one-half inches in diameter, thus showing the strong probability that there are a few isolated cases of rot occurring at different points early in the summer, from which the later attack largely spreads.

EXTERNAL APPEARANCE OF THE DISEASE.

The bitter rot can be detected with considerable certainty in its early stages. The first indication of the trouble is a small circular spot, usually on the smooth, unbroken surface of the fruit. The epidermis of the diseased area becomes a pale brown color, with sharply defined borders of a darker hue, and sometimes a purple stain surrounds the spot. The tissue is slightly sunken, the skin appears to be thin and papery, but shows no trace of external injury. The size of the spot increases by concentric areas of tissue until the fruiting pustules appear, after which it does not always maintain so strictly the circular form. When the disease is developing rapidly, several spots appear upon the same fruit simultaneously, and these often coalesce and soon involve the entire fruit in decay.

It never occurs in this disease, as in black rot of apple, that the whole surface will show fruiting pustules. In fact, the fruiting organs of bitter rot ordinarily occur only on a limited area about the point of infection. This will be larger or smaller according to the rapidity with which the fruit decays. I have seen one-half of the surface of a diseased specimen covered with pustules; this, however, is exceptional. Pustules do not form after the fruit has decayed, and this disease does not develop in fruit already decaying from other causes. The mycelial threads (plant body of the fungus) grow rapidly through the tissues of the fruit, and even when the diseased area is small in diameter, it will be found to extend deeply into the tissue, frequently quite to the center of the fruit. Fruits which decay from this cause shrivel up and become dry and hard, and may frequently remain hanging upon the trees over winter. Normally, however, they fall to the ground, and the fruit wholly decays in this moist situation.

Black rot of the apple, *Sphaeropsis malorum*, Berk., is at times associated with bitter rot by reason of the fact that, that fungus occasionally invades the specimens of fruit already decaying from the latter disease. This fact may cause some confusion on the part of persons who do not discriminate carefully between the two forms of rot. In the case of black rot, eventually the whole surface of the decayed fruit shows fruiting pustules, and this is never true of bitter rot.

The fruiting pustules of bitter rot make their appearance early in the progress of the disease, usually when the diseased area is not larger than a silver dime. They appear as slightly raised points beneath the epidermis, and usually of lighter color than the decaying tissues, but in some instances are dark and shiny. In most cases the fruiting stroma will rupture the epidermis over the pustules by the time the diseased area attains the size of a twenty-five-cent silver piece, but this depends upon local conditions, and cannot be stated with certainty. After the epidermis has ruptured, and the spores washed away, the openings are ragged, and the tissue within seems blackened. In the centre of the diseased spot the pustules are generally massed closely, and then arranged somewhat in concentric rings around this point.

Figure 1, Plate III, is a free-hand drawing from nature, showing a

fruit with several rot spots in course of development. An attempt is made to show the appearance of the pustules after the epidermis is ruptured and spores are still attached, but this is not wholly successful. Under normal conditions—i. e., in the orchard—the spores are washed away by storms or dew, and one sees only the ragged edges of the ruptured epidermis, and the remains of the fruiting stroma, which at this stage gives the pustule a black charred appearance. But in the laboratory, where protected from disturbance a heavy mass of spores are extruded from the ruptured pustule, and these ooze out in the form of globules and remain adhering to the fruit. These masses of spores have a pale flesh-pink appearance, and the drawing above referred to attempts to show this character of the spore mass *in situ* on the fruit. The black rot never shows this mass of spores resting upon the epidermis of the fruit.

MICROSCOPIC CHARACTERS OF THE PUSTULE.

If a portion of the diseased tissues be properly hardened and then imbedded in a suitable manner a thin section can be made which will, under the microscope, show the characters delineated in Figures 2 and 3, Plate III. Figure 2 shows a pustule before the epidermis is ruptured. The inception of the pustule is a dense stroma or cushion of very pale, delicate mycelium, which forms just beneath the epidermis by the segregation and branching of numerous coarser strands of the mycelium. These become much branched and interwoven, and eventually give off the dense mass of upright branches of hyphae which press outward upon the epidermis and rupture it. The hyphae are much interwoven among themselves and septate as shown in the drawing. These constitute the fruiting *hyphae*, or spore-bearing organs, as shown in full fruition at Figure 3 of the same plate. There is no regularity as to size or dimension of a pustule, or the number of fruiting hyphae it will produce, but the general characters are shown in the drawings. It must be borne in mind that Figure 3 is from material preserved in the laboratory; specimens taken from the orchard will not show such a mass of spores *in situ*.

Spores in artificial cultures on agar-agar are borne in masses resembling the regular pustule upon fruit of apple, and are also borne upon free mycelial threads without any regularity whatever. This

latter form of fruiting is represented at Figure 4, Plate IV. The spores borne in this manner resemble in general characteristics those borne in pustules on fruit. They are borne singly on separate branches or on clusters of short-branched hyphæ or apically upon a normal branch of mycelium. The spores behave under culture exactly like those from normal pustules on fruit.

The spores, as shown in Figure 3, Plate III, are abjoined from the apex of the fruiting hyphæ in vast numbers, and if the specimen is carefully isolated under proper conditions they will eventually form in such quantity as to cover the entire surface occupied by the pustules with a pinkish mass. The period of spore bearing is only limited by favorable conditions and exhaustion of the nutriment.

DESCRIPTION OF THE SPORE.

The spores individually are too small to be distinguished with the unaided eye, and their pinkish appearance in mass has been noted above. Viewed separately, with sufficient magnification they appear as shown in Figure 1, Plate IV. The general shape is oblong, rounded at ends, some tending to long, cylindrical shape, and occasionally slightly curved. But this applies only to normal spores, or what we have decided to call the ordinary form as it occurs upon fruit of apple. On other media they may vary so as to render any description save color and germination unrecognizable. I have, in the same cultures, on sterilized potato and apple, produced spherical, dumb-bell shaped, oblong, ovoid, and cylindrical spores. The spherical spores measured 6 to 8 μ ., ovoid spores 4 x 10 and 6 x 12 μ ., and cylindrical spores 6 x 30 to 4 x 40 μ . This statement will serve to show how unreliable are any statements of spore measurements unless the conditions are known, and even then influences unnoticed by the observer may affect the result. Our observations show measurements of normal spores to be about 4 x 10 to 6 x 12 μ . Saccardo, however, says the normal spore is 20 to 30 μ . long. In very rare instances we produced spores of this length in cultures, but in no instance found them growing normally. These long spores were usually slightly curved. The secondary spores, which will be mentioned later, are about 2 μ . shorter than primary spores.

The color of the spores under the microscope, of whatever shape

or size, is characteristic, and is a delicate pale green, with hyaline cell walls and finely granular protoplasmic cell contents; spores, without exception, are one-celled. This statement does not exactly agree with that of some others, but it holds true in our observations, which comprise a large number of cultures on various media, extending over a period of several years.

GERMINATION OF THE SPORE.

Fresh spores from a fruiting pustule will germinate readily in three to five hours in water or any favorable medium. The phenomena of germination are marked by a retraction of the cell contents from the outer wall of the spore and division into two or more portions more or less, distinctly cut off by cross septa. As many as four septa have been observed in a single spore. The germ tubes are usually developed at or near the poles of the spore, and vary in number from one to two, or even three, from a single spore.

A peculiar phenomenon occurs very often during germination, which is illustrated at Figures 2 and 3, Plate IV. This consists in the formation of secondary spores with or without coalescence of germ tubes, or of a germ tube with another spore. This was observed very often, both in water cultures and on agar-agar media, but more perfectly upon the latter. In some instances nearly every spore would unite with another either directly by a short process or by union of germ tubes, and in all cases of coalescence, so far as observed, a secondary spore was formed; there occurred no true mycelium. But on the other hand, when secondary spores were borne on a promycelium without coalescence, a true mycelium might be and was frequently produced from the same spore at the opposite pole from the promycelium.

The conditions which controlled the coalescence of spores or of germ tubes, or the production of promycelia and secondary spores, or of true germ tubes, were not determined. All of these forms occasionally occur in the same culture within the field of a one-fourth-inch objective.

In many instances, on sowings in agar-agar tubes, secondary spores were produced to such extent as to pile up in pinkish masses about the point of infection, in appearance like a regular fruiting

pustule on fruit. Later mycelial growth developed and produced true fruiting pustules, and also bore spores upon free mycelia, as shown at Figure 4, Plate IV.

The promycelia vary much in length, are much septate or divided by cross walls, and are of greater diameter than true germ tubes. They were measured 4 to 6 μ . in diameter, and 16 to 40 μ . long. The secondary spore is in all cases borne at the apex of the promycelium, and so closely resembles the parent spore as not to be distinguishable. The only difference has already been mentioned—viz., the shorter length, and this is of no consequence in such a variable form. The true germ tubes are more delicate than promycelia, and do not at once become septate. Their average diameter is 2 to 4 μ . In the process of germination the spore becomes more or less exhausted of protoplasmic contents by the passage of this substance into the germ tube. The promycelium usually exhibits much denser cell contents than the true mycelium; in fact, the latter is normally hyaline in its early stages, with slightly granular cell contents. The period of time during which the spores may retain their vitality is not yet known definitely, but I have succeeded in germinating them after a period of sixteen months, during most of which time they lay perfectly dry in the laboratory. Spores exposed in moist situations invariably germinate, so far as our observations cover this point, and thus their vitality is lost.

CHARACTER OF THE MYCELIUM.

The normal mycelium is delicate, hyaline, much septate and constricted at septæ, as shown at Figure 5, Plate IV. Cell walls pale, contents very slightly granular, granulations usually showing more prominently in vicinity of septæ. It grows rapidly and ramifies widely through the substratum; is intercellular, and branches with great frequency. The strands vary in diameter from 4, 6 to 8 μ . In the diseased fruits they are readily found, and penetrate to a considerable depth, causing the decay to soon extend to the centre of the specimen. Infection is readily made on artificial media, or on fruits by use of a portion of the diseased tissues taken from some distance below the epidermis, thus using mycelium instead of spores

for infective material. The mycelium is not evanescent though delicate, and persists in decayed specimens for months.

LATER STAGES.

As already stated, the affected fruit shrivels and dries up if it remain upon the tree, or is preserved where it is exposed to ordinary atmospheric conditions. Upon the ground it will ordinarily entirely decay and disappear. On the dry specimens the remains of the pustule of bitter rot is easily distinguished from other forms of rot on the apple. If a section be made, the dried and blackened remains of the fruiting stroma are clearly distinguished, and the darkened mycelial threads are prominent in the decayed tissue, Plate IV, Figure 6. Ordinarily it will be found that many of the fruiting hyphæ have disappeared, and that none of those remaining reach what was the summit of the pustule during its active fruiting stage. The drawing, Figure 6, Plate IV, shows the setæ or dark clavate bodies which are found quite constantly in the old pustules, varying from a very few to a considerable number, and resemble those characteristic of the genus *Colleototrichum*. I have never found these setæ in a pustule during its active period of spore bearing.

The discovery of the ascigerous stage of this fungus by Clinton and others has not been verified here, though we have searched for it on the decayed fruits.

SOURCES OF INFECTION.

The sources from which each annual recurrence of bitter rot starts are of much practical importance, and some recent investigations have raised very important scientific and practical questions along this line. If it is possible to discover and remove the source or sources of infection, and thus to check the disease at its earliest inception, much may be accomplished in the way of preventing the disastrous spread in the later season. The recent claims of Burrill and Blair and of Von Schrenck and Spaulding in regard to the canker on the apple limbs being the source, or one of the chief sources, of the early

infection, has led us to examine the evidence along this line. First I will consider

THE MUMMIED FRUITS.—In the past the mummied fruits hanging to the trees, or the rotted fruits upon the soil, have been looked upon as the source from which the spores are derived for each annual infection of the growing fruit. Hasselbring made direct observations upon the mummied fruits which proved the production of spores therein, and that these spores would produce the bitter rot when inoculated into growing fruit. The writer has also proven that spores will retain their vitality for more than a year if kept from conditions of moisture which favor germination. Thus it might be possible that spores of the previous year may play some part in spreading the disease each season. From many observations I am also led to suspect that the rotten fruit upon the ground may produce spores from which infection of the growing fruit occurs. Laboratory studies by the writer and various workers in plant pathology have abundantly proven the readiness with which this fungus grows upon a large number of nutrient substances. Certainly it will grow most luxuriantly upon cooked apples, potatoes, turnips, etc., and will produce conidia spores in the greatest abundance upon these substances. Consequently, if this fungus is able to persist upon decayed fruit and grow as a saprophyte upon such fruit, lying on or in the soil, this would prove an abundant source of infection each succeeding year.

OBSERVATIONS ON INFECTION FROM MUMMIED AND DECAYED FRUIT.—The illustration, Figure 2, Plate I, shows a drawing from nature made this past season. I have frequently observed its counterpart. In this instance a mummied fruit attached to an old fruit spur hung between partially grown fruits of the current year. There were three fruits in the cluster, all diseased, but only two could be effectively shown in the drawing. These fruits were on the outer extremity of the branches about eight feet from the ground, and no sort of canker on the twigs or limbs could be found. The tree is a fourteen-year planted black twig. A fairly well marked outbreak of rot was present on a number of fruits below this cluster. The tree as a whole suffered only a small percentage of loss.

Another case which I could not well illustrate was carefully observed on Missouri Pippin, which always rots badly with us here. On the

9th of July I had found one fruit showing bitter rot on one of the trees of this variety. This fruit was on the extreme outer portion of limbs, about three feet from the ground, no mummied fruits or limb cankers in any wise associated with it. Other fruits were hanging close all around this one, but showed no signs of rot for more than ten days after this was observed. But on the tree of same variety adjacent to this tree, where we were at first unable to find the rot, there occurred a serious outbreak shortly after the above date. This occurrence was in the midst of the branches about four feet from the ground and well shaded. Two very obscure mummied fruits situated a few inches apart were found just above the attacked fruits, and by July 22d, within a radius of two and one-half feet of these mummies, thirty-three attacked fruits were counted. Not a limb canker or other visible source of infection could be found. There were no decayed fruits at higher points in the tree. Like observations could be multiplied.

There is also strong evidence that the disease in some manner starts from sources on the soil. This has been noted for years, but the past season we took especial pains to watch for the inception of the attack on a number of trees, and in nine cases out of ten it began on the lower limbs. The station orchards are pruned to low heads, and when in fruit many of the branches become so procumbent as to touch the ground. It was upon these lower limbs the disease first made its appearance in such large percentage of cases as to seem to prove that they were in close proximity to the source of infection. This fact was so marked with Peach Pond that the most casual observer would remark it. The fruit was simply stripped from the trees in successive strata from below upwards. With Bentley, and also with some other varieties, the very striking fact that the fruit on the lower branches was wholly involved before there was any rot in the top of the trees, presented strong evidence of a near-by source of infection. Diligent search of the limbs failed to show any bitter rot cankers on these varieties mentioned.

These specially susceptible varieties usually show the trouble four to six weeks before it becomes general in the orchard, and the progress of the disease from below upwards is not so marked on these varieties which do not suffer attack until late in the season. It may readily be presumed that these trees which suffer so badly in the early season

become sources of infection to others, and the later attack may first show in the top, or anywhere upon the tree.

By the 28th of August Peach Pond was stripped of fruit, except a few mummies; Bentley showed no sound fruit, and most of the crop was on the ground; Missouri Pippin was not suffering so badly, but it was double sprayed; Newton Pippins showed slight trouble.

THE LIMB CANKERS AS SOURCE OF INFECTION.—The publication in July, 1902, by Burrill and Blair of their observations on the so-called bitter rot canker, and later publications by Von Schrenk and Spaulding along the same line, have raised a question of the utmost importance in connection with the annual recurrence of outbreaks of this disease. There cannot now remain the slightest doubt but that these gentlemen have found the bitter rot fungus growing and producing spores in "cankers" on the apple limbs. Dr. Burrill has very kindly furnished me an apple limb showing a canker in which the parasite in question was unmistakably present and fruiting. It may also prove true that the statements of these gentlemen to the effect that the "Bitter Rot Cankers" on the apple-tree limbs are the chief sources of the reinfection of the fruit each succeeding year in the districts in which these observations were made. But careful observations made here the past two summers show that these statements do not apply to the occurrence of the bitter rot in the station orchards here. We had for some time been observing the cankers on both apple and pear in connection with an investigation on black rot of the apple, *Sphaeropsis malorum*, and of the pear blight and twig blight of apple. In no instance have we been able to find the presence of the bitter rot fungus on the limbs or trunks of apple or pear, though we have especially watched for its occurrence since the appearance of the publications cited.

During the past summer and fall the bitter rot caused immense damage in the apple orchards in some portions of Virginia, and so far as able, the writer visited the orchard sections for the purpose of making observations on the trouble and the probable sources of annual reinfection of the fruit. Canker spots on the limbs of the older apple trees were found in plenty, especially in those sections where twig blight commonly occurs. The illustrations, Plate II, show types of these cankered limbs, and Figure 1, Plate I, shows what

seemed to me to be the inception of the canker spot. In this latter figure we have an example of the very commonly observed twig blight. The small twig has died back to the branch, and the bark about its base has also died apparently from the blight, and the cankers of later growth, as shown in Plate II, almost always show the remains of a dead twig somewhere on their surface. There is strong reason to believe that the twig blight is, with us, the inception of the canker. In no case were we able by observation to trace the slightest connection between cankered limbs and the occurrence of rotted fruit. Later microscopic examination of some of the more promising material failed to show any trace of the bitter rot fungus in the canker spots.

We have frequently found the bitter rot present where no trace of cankered limbs could be found, and the cankered limbs without the presence of bitter rot. The often remarked occurrence of this trouble on the fruit of young, healthy, smooth trees bearing their first crop shows plainly that we are not yet warranted in attaching much importance to the cankered limbs as the source of infection in this State. *Consequently we suggest that our apple growers should be slow to undertake severe pruning in order to remove cankered limbs.* When pruning is necessary, if these injured limbs can be cut away without harm to the tree, this course is advised, but we advise against attempts to control bitter rot by cutting out the cankered limbs.

No fruit grower in this State has reported to us reliable observation which in any wise connects the outbreak of bitter rot with the canker. Some have remarked in their correspondence that the cankers are the source of the infection, but this is scarcely convincing. It would be a great service if fruit growers would observe this matter closely in future, and report any observations they may make and send us specimens for verification. This question was referred to a number of the best specialists on fruit diseases in the Atlantic Coast States, and without exception they have so far reported that they have not observed that the "cankers" are the source of the bitter rot infection. The mummied fruits are universally regarded as the chief source of primary infection.

PERIODIC SEVERITY OF THE DISEASE.

After such an experience as the past summer and autumn, some growers are inclined to despair of future success; but if they were to consult the literature of the subject, they would find that these severe outbreaks are periodic. They have recurred three or four times during the past fifteen years in Virginia, and the older literature gives accounts, dating back thirty years or more, which show that our recent experience is not unusually severe. The trouble is always present in the orchards, and wherever climatic conditions favor a strong development of the disease in the early summer, then the fruit is sure to suffer severely. The conditions which promote the development of the disease are frequent showers interspersed with hot sunshine, and especially hot, damp nights. Under such conditions one must watch for the early outbreak and be prepared to check it, even if entire removal of the fruit from the trees first attacked becomes necessary.

During the past dozen years the writer has made observations on this trouble, and has come to believe that attention to variety selection, to soil conditions, to location as affected by atmospheric phenomena, and the use of remedial sprays, will enable the growers to largely circumvent it. On several occasions I have made inquiries of growers and specialists on these and other points, and think that a brief summary of such data as falls within the scope of this paper may be helpful.

VARIETIES MOST SUSCEPTIBLE TO BITTER ROT.

From the fruit section east of the Blue Ridge, Albemarle Pippin is, almost without exception, reported as the most susceptible to bitter rot. The reports for this past season summarized read as follows:

Albemarle Pippin, 10 to 100% destroyed.
York Imperial, 1 to 80% destroyed.
Ben Davis, 1 to 75% destroyed.
Winesap, 1 to 50% destroyed.

Many other varieties are mentioned, but these constitute those of greatest commercial importance.

For that portion of the State west of the Blue Ridge, Albemarle Pippin is again placed at the head of the list as the worst affected by bitter rot. Though the Pippin is only grown in a few localities west of the Blue Ridge, it is still an important crop where grown.

The summary of reports received the past season is as follows:

Albemarle Pippin, 2 to 90% destroyed.
 York Imperial, 1 to 25% destroyed.
 Ben Davis, 1 to 25% destroyed.
 Winesap, 1 to 5% destroyed.

The York Imperial is at present doubtless the most important commercial apple west of the Blue Ridge mountains. Arkansas (Black Twig) and others are, however, coming into favor.

We wish to state that the above figures are not intended to indicate that this percentage of the total fruit crop was destroyed the past year by bitter rot. They are only estimated percentages given by the persons reporting, based on what they had seen, and are to be taken as indications of the susceptibility of these varieties, and not as implying a statement in relation to the real loss suffered. Estimates of total loss, either in bushels or money value, are apt to be quite misleading unless the data is most carefully made up by an experienced observer covering carefully the territory included in the same. Everywhere the light colored varieties seem more susceptible to bitter rot than highly colored fruits.

VARIETIES LEAST SUSCEPTIBLE TO BITTER ROT.

The same observers who reported the above estimates also stated their preferences as to varieties best suited to their localities, in so far as freedom from this disease is concerned.

For the section east of the Blue Ridge the ratings of the several varieties reduced to percentages are as follows:

Winesap	45%	place it first.
York Imperial	35%	place it first.
Ben Davis	12%	place it first.
Albemarle Pippin	4%	place it first.
Arkansas (Black Twig)	4%	place it first.

It must be borne in mind when considering this result that Winesap can be grown everywhere that Pippins can be grown, and over a large area where Pippins cannot be successfully grown. York Imperial is really so cosmopolitan that it can be grown where any apple is ordinarily successful.

The reports for the sections west of the Blue Ridge, when expressed in percentages, read as follows:

York Imperial	33%	place it first.
Ben Davis	30%	place it first.
Winesap	25%	place it first.
Grimes	10%	place it first.
Arkansas	2%	place it first.

These summaries appear to have value. However, in my judgment, the percentage value on Ben Davis for the western section of the State is too high. The figures ought, however, to have their chief value in leading growers to select with care the varieties to be grown, and in inducing fruit growers to observe closely in the future the prevalence or freedom from bitter rot and other troubles, and preserve such data for their future guidance.

RELATION TO SOIL, SITUATION, ETC.

The inquiries made along these lines have not elicited much definite information from fruit growers that can be summarized. There seems to be no unanimity of opinion as to whether Pippins, for instance, rot less upon red land or dark loam land. There seems, however, considerable unanimity of opinion that trees in shaded mountain hollows show less rot than equally good trees in situations more exposed to hot sun. Good observers say that the elevation has nothing to do with prevalence of the rot where the premises have once become infested.

As to treatment with Bordeaux, only a few statements reported by growers have definite value. It is still true that many of our orchardists have not learned the details of the spray work well enough to make their efforts very effective against a disease like bitter rot. So many elements of difficulty surround this work, and in spite of the most painstaking efforts, some varieties will rot anyhow, hence

one is not surprised at the tone of discouragement which occurs in these reports. Yet there are positive statements of good results from the effects of spraying. One reporter says fifty trees which were sprayed five times after the blooms dropped showed very little rot, and that the fruit from these trees brought sixteen shillings per barrel in Liverpool, when fruit from the unsprayed trees brought six to seven shillings. Another thoroughly competent orchardist says that with five sprayings he held the rot almost entirely in check. Others speak of holding the rot in check until late in the season, and then it became as bad on the sprayed as on the unsprayed fruit. Query: Did he keep the fruit covered with the spray? The Bordeaux Mixture is effective only so long as the fruit is covered by it. To keep the smooth, rather greasy surface of the apple fruit covered is one of the very difficult operations in spray work.

SUGGESTIONS ON TREATMENT.

Up to the present, so far as known to the writer, no thoroughly satisfactory study of remedial measures for this disease has been made. Sporadic and incomplete efforts to control the bitter rot by the use of Bordeaux Mixture, ammoniacal copper solution, sulphate of potassium, etc., etc., have been frequently made, but no convincing statements as to just how to proceed to its rational and safe control has come to our notice. The serious difficulties attendant upon the treatment of such a trouble is responsible for this somewhat chaotic condition of affairs. A result to command confidence must show what can be accomplished in a series of years in comparison with unsprayed fruit of the same variety and grown under like conditions. So far as my own observations and experiments go, I am sure the first step ought to be directed to—

REMOVING THE SOURCES OF INFECTION.—It appears to be well established that the mummied fruits hanging to the trees and the rotted fruits upon the soil constitute in large measure the source of the annually recurring infection. To my mind these fruits are *the source* of infection. Then they should be removed. I have often suggested in correspondence to growers that they remove the growing fruit just as rapidly as it shows rot. This has been practiced on a large scale in Illinois, according to Burrill and Clinton. In 1901 we

first resorted to this practice in the Station orchards, with apparently very beneficial results, as the spread of the rot was stayed through this effort, coupled with the application of spray washes.

However, we have never found that removing the mummied and rotted fruits, or the growing fruit as it begins to show rot, will wholly prevent the disease. If promptly and efficiently followed, these practices accomplish good, but are not sufficient. All diseased fruit removed should be so disposed of as to prevent dissemination of the spores. Possibly burying is the simplest plan. We are now prepared to say that in many instances we believe it would be very wise to remove certain varieties or certain trees on which the disease seems to start. Intelligent observation must determine such points. As stated under a previous section, we are not ready to recommend extreme efforts to cut out all cankered limbs in Virginia orchards. There is as yet not sufficient evidence to warrant such a step; but they should be cut out whenever in the ordinary course of pruning this is found possible.

We have strong ground for saying that the second, and perhaps most important, step in the way of remedial measures should be the—

APPLICATION OF SPRAYS.—In saying this we do so fully realizing the fact that there is evidence against hopeful results. But the best results from experiment stations, and the best work accomplished by fruit growers, indicate clearly the value of the Bordeaux spray.

The time and method of application of the spray is so essential that no result of value can be hoped for unless these details are observed. There is no proof that winter washes of any kind applied to the trees will lessen the disease. Yet on general grounds we advocate winter washes as a part of a rational system of treating the orchard. There is also no evidence that the early spring sprayings recommended in our Bulletin 100 have any effect whatever upon the prevalence of bitter rot. These early treatments are very essential to the health and vigor of the orchard, and should be made as directed in the Bulletin above cited, and if omitted may, and in many cases will, result in worse damage to the orchard than ordinarily occurs from the bitter rot fungus; but we wish to be clear that these early treatments are not to be considered as primarily affecting the bitter-rot question one way or the other. If they do, no one has yet proven

this fact so far as appears in the literature. The most careful early sprayings here have been wholly negative as to results against bitter rot.

This brings us to the point where we wish to say that, in our opinion, the only spray treatment of value for this trouble is that which is applied directly to the fruit. The treatment being preventive, and not curative, the application must be made in advance of the infection. In all our observations the rot has never appeared before the first of July, consequently we advise that spray treatment for this trouble should not begin before that date. If the season is favorable to rot—viz., sultry, with hot sunshine and showers—and the set of fruit warrants, the first application should be made about the date mentioned above—say July 1st to 10th. The grower should also watch carefully for the first appearance of the disease upon the fruit. If the spray has not been applied when the disease is first observed, make the application at once. If the fruit *has been sprayed*, and the characteristic *rot spots appear*, *respray the fruit at once*. One cannot do more than keep the fruit covered with a thin coat of the spray preparation. If the Bordeaux is properly made and applied, it will adhere some times for weeks, and I have known it to adhere for two months on some varieties. The recommendations as to specific number of applications to be made have no value. This must always depend upon the judgment of the grower, and be governed by weather conditions, etc.

HOW TO MAKE THE BORDEAUX.—We have often published instructions on this point, but repeat them for the benefit of those who may not have our former Bulletins on file. Take two sound barrels—fifty-gallon oil barrels preferred—remove one head from each, and clean them perfectly of all dirt and residue of whatever sort; place these barrels at the water supply, and in one put forty pounds of copper sulphate, in the other pour the clear strained paste made from slacking fifty pounds of stone lime; fill the barrels with water, and as soon as the bluestone is dissolved the material is ready for use. It is very important that the materials put into these stock solutions should be free from detritus of any sort, otherwise there will be trouble from clogging of the nozzles. There should be a long-handed stirrer in

each barrel, and if the bluestone is stirred occasionally it will the sooner come into solution.

This manner of making the stock solutions is designed to work conveniently for the preparation of the weak Bordeaux recommended by us. Thus five gallons of each solution taken with the necessary water to fill a fifty-gallon barrel makes exactly the 4-5-50 Bordeaux recommended for general work, but for spraying the fruit for bitter rot we prefer to recommend a weaker spray because of danger of russetting the skin of the apples. Hence of these stock solutions we take four gallons from the copper sulphate barrel and five gallons from the lime barrel to each fifty-gallon cask of spray. This makes a formula of about three pounds copper sulphate, five pounds lime, and fifty gallons of water.

To make the Bordeaux, fill the barrel to which the pump is attached about half full of water, pour into this the copper sulphate solution, then add the lime, at the same time filling the barrel full of water. Keep the stock solutions well stirred when taking out the quantity desired for the preparation. The Bordeaux made in the dilute solutions here indicated is of better quality than when the full strength stock solutions are poured together. This formula makes a preparation that adheres well.

HOW TO APPLY THE BORDEAUX.--We have come to think that only one nozzle should be used on each lance when treating bitter rot. This should be a Vermorel with about 1-16-inch opening in the cap. It is important to use only enough of the preparation to finely mist the fruit, for if enough is used to cause it to flow on the fruits, they are not nearly so well covered as when it is applied in a fine mist. The gang nozzles throw the spray in such quantity that the workman cannot take pains to hit all the fruits and properly distribute the spray without applying too much material. The pumps best adapted to use in this work are those which have the piston working in a short cylinder or dash-pot, and a large cylinder or pressure reservoir to which the discharge pipes are connected. The Morrill & Morley Co., Benton Harbor, Mich.; the Deming Co., Salem, Ohio; the Goulds Manufacturing Co., Seneca Falls, N. Y., all make pumps of this type. It is best to purchase a pump sufficiently powerful to carry two discharge pipes, and we find the hose connection should

be at least fifteen feet long, and for large trees twenty feet is better. To these hose lines should be attached the bamboo extension rods, as illustrated in our Bulletin No. 100. It is best to have on hand a supply of nozzles, so as to avoid delay through loss or accident to these parts. This outfit is the same that we have recommended for years for general orchard work.

I wish to acknowledge my indebtedness to Mr. J. F. Strauss for the drawings made by him for illustrating this Bulletin.

WM. B. ALWOOD,

Issued February 20, 1904.

Mycologist

EXPLANATION OF PLATES.

PLATE I.

- Fig. 1. A characteristic case of twig blight, and apparently the early stage of limb "canker."
- Fig. 2. Outbreak of bitter rot in association with mummied fruit.

PLATE II.

Representative specimens of "cankers" on apple limbs. Specimens collected from various orchards the past autumn.

PLATE III.

- Fig. 1. A drawing from nature, showing a fruit attacked by bitter rot.
- Fig. 2. A cross section through a fruiting pustule, showing the development of the mycelial strands which produce the spores.
- Fig. 3. Fully developed pustule discharging spores.

PLATE IV.

- Fig. 1. Individual spores, greatly enlarged.
- Fig. 2. Spores germinating with promyces and forming secondary spores.
- Fig. 3. Spores germinating with true germ tubes.
- Fig. 4. Production of spores on free mycelium.
- Fig. 5. Characteristic mycelial strands as it occurs in decaying fruit.
- Fig. 6. Section through an old pustule on fruit which has lain out over winter.



Fig. 1—Twig blight, commencement of limb canker.



Fig. 2—Bitter Rot starting from mummied fruit.

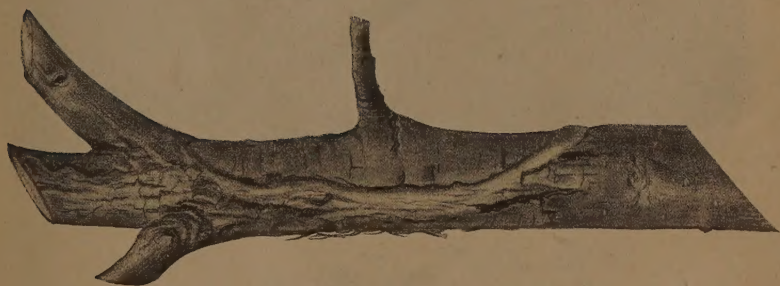
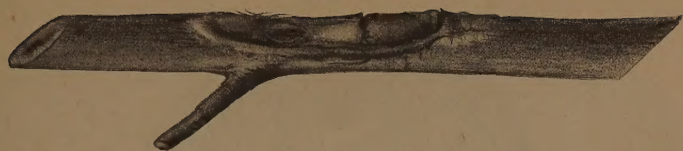
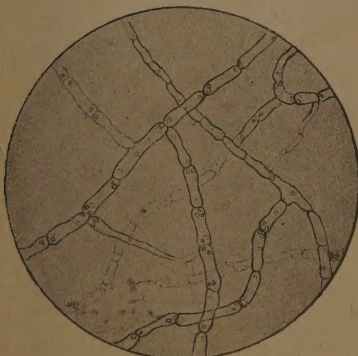


PLATE II.—Cankered apple limbs.

*Fig. 1.**Fig. 2.**Fig. 3.*

*Fig. 1.**Fig. 2.**Fig. 3.**Fig. 4.**Fig. 5.**Fig. 6.*

